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(54) Title: NON-SYMMETRIC ARRANGEMENT OF FUEL NOZZLES IN A COMBUSTOR

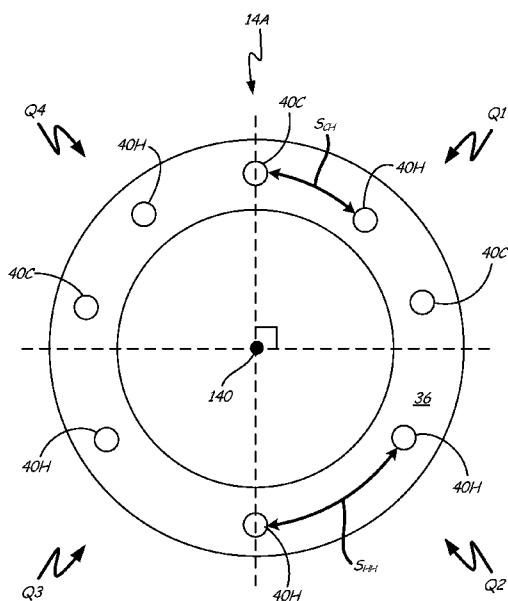


FIG. 4

(57) Abstract: A fuel nozzle arrangement includes an annular combustor (14A - 14D) having four quadrants (Q1 - Q4). Fuel injectors are located in the four quadrants (Q1 - Q4) and each fuel injector has either a first or second type nozzle (40H, 40C) attached to it. The first and second type fuel nozzles (40H, 40C) are located in an array so that at least two of one nozzle type are located together to allow for non-uniform injector spacing with uniform downstream temperatures.

NON-SYMMETRIC ARRANGEMENT OF FUEL NOZZLES IN A COMBUSTOR**BACKGROUND**

The present invention relates generally to gas turbine engines and, more particularly, to fuel injectors used in gas turbine engines. Gas turbine engines are rotary-type combustion turbine engines built around a power core made up of a compressor, combustor and turbine, arranged in flow series with an upstream inlet and downstream exhaust. The compressor section compresses air from the inlet, which is mixed with fuel in the combustor and ignited to generate hot combustion gas. The compressor section may include a low, mid, and high pressure compressor sections. The turbine section extracts energy from the expanding combustion gas, and drives the compressor section via a common shaft. The turbine section may include a low, mid, and high pressure compressor sections. Expanded combustion products are exhausted downstream, and energy is delivered in the form of rotational energy in the shaft, reactive thrust from the exhaust, or both.

Gas turbine engines provide efficient, reliable power for a wide range of applications in aviation, transportation and industrial power generation. Small-scale gas turbine engines, such as auxiliary power units, typically utilize a one-spool design, with co-rotating compressor and turbine sections. Larger-scale combustion turbines including jet engines and industrial gas turbines (IGTs) are generally arranged into a number of coaxially nested spools. The spools operate at different pressures, temperatures and spool speeds, and may rotate in different directions.

The combustor includes a plurality of fuel injectors arranged in an annular array about a central axis of the combustor. The fuel injectors atomize and inject fuel into the combustion section of the gas turbine engine. Attached to each fuel injector is a fuel nozzle which controls the exit pattern of the fuel from the injector. Different types of fuel nozzles are used to provide different fuel flows into the combustor, examples of which may include duplex and simplex nozzles. The varying fuel flows provided by different types of nozzles cause some nozzles to burn hotter than others. The difference of combustion temperatures between the hot and cold nozzles causes a non-uniform circumferential temperature gradient throughout the engine.

The fuel injectors are typically arranged in an equally spaced symmetric array within the combustor. However, a symmetric fuel injector assembly can cause significant problems within the combustor due to the non-uniform circumferential temperature gradient. Problems often include burnout of combustor wall surfaces, decrease in combustor stability, fuel puddles, hot starts, compressor stalling, high amplitude combustion noise, limited turndown, premature wear, and high cycle fatigue cracking of structural components in the combustor, see U.S. Pat. Nos. 4,548,032 and 5,551,228; and U.S. Pat. App. No. 2012/0125006 A1. Previous attempts have been made to eliminate these problems by manipulating the pattern of fuel flowing from a symmetrical annular array of fuel nozzles to provide an asymmetrical fuel pattern across the combustor, for example, see previously discussed U.S. Pat. No. 5,551,228.

SUMMARY

A fuel nozzle arrangement includes an annular combustor having four quadrants. A plurality of fuel nozzles is disposed in the four quadrants. Fuel nozzles of a first and second type are disposed onto the fuel injectors so that each fuel injector has either a first or second type nozzle attached to it. The first and second type nozzles are arranged in an array so that at least two of one nozzle type are adjacent to each other.

A gas turbine engine includes a compressor section. The combustor receives air from the compressor section. A turbine section receives combustion gases from the combustor and drives the compressor section. The combustor includes a circumferential array of gas turbine engine fuel nozzles in a non-symmetrical pattern.

A fuel nozzle arrangement includes an annular combustor. A plurality of fuel nozzles is disposed in the combustor. Fuel nozzles of a first and second type are disposed onto the fuel injectors so that each fuel injector has either a first or second type nozzle attached to it. The first and second type nozzles are arranged in a non-alternating pattern of first and second type nozzles.

A fuel nozzle arrangement includes an annular combustor. A plurality of fuel nozzles is disposed in the combustor. Fuel nozzles of a first and second type are disposed onto the fuel injectors so that each fuel injector has either a first or second type nozzle attached to it. The first and second type nozzles are arranged in a non-uniformly spaced circumferential array.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side view of a prior art gas turbine engine.

FIG. 2 is a sectioned side elevation view of a prior art annular combustor.

FIG. 3 is a simplified line drawing of a prior art combustor taken substantially in the
5 direction of line 3-3 in FIG. 1.

FIG. 4 is a simplified line drawing of an elevation view of a combustor according to a first embodiment taken substantially in the direction of line 3-3 in FIG. 1.

FIG. 5 is a simplified line drawing of an elevation view of a combustor according to a second embodiment taken substantially in the direction of line 3-3 in FIG. 1.

10 FIG. 6 is a simplified line drawing of an elevation view of a combustor according to a third embodiment taken substantially in the direction of line 3-3 in FIG. 1.

FIG. 7 is a simplified line drawing of an elevation view of a combustor according to a fourth embodiment taken substantially in the direction of line 3-3 in FIG. 1.

DETAILED DESCRIPTION

15 FIG. 1 schematically shows conventional gas turbine engine 10 including compressor 12, combustor 14, and turbine 16. Compressor 12 is disposed forward, that is upstream with respect to flow, of combustor 14, and turbine 16 is disposed aft, that is downstream with respect to flow, of combustor 14. Compressor 12, combustor 14, and turbine 16 are generally coaxially disposed about central axis C which constitutes the centerline of gas turbine engine
20 10. A plurality of fuel injectors 20 is disposed in a circumferential array in combustor 14.

FIG. 2 illustrates prior art combustor 14, which is disposed concentric with the engine axis C. Combustor 14 includes annular combustion chamber 30 defined by radially inboard liner 32, radially outboard liner 34, and bulkhead 36. Bulkhead 36 extends between the respective upstream ends of inboard liner 32 and outboard liner 34. Collectively, inboard liner
25 32, outboard liner 34, and bulkhead 36 bound the annular combustion chamber 30 and define a combustor interior volume that extends longitudinally within the annulus formed by the inboard liner 32 and the outboard liner 34 from the bulkhead 36. Bulkhead 36 carries fuel injectors 28 disposed in a circumferential array at spaced intervals about the annular combustion chamber 30. Each fuel nozzle 40 is disposed at the end of a fuel injector 20 (FIG.
30 1) that extends through outer case 42 of combustor 14 to convey fuel from an external source

to the associated fuel nozzle. Each fuel nozzle **40** injects fuel through a spray head into a central stream of air emitted along the centerline of the fuel nozzle.

FIG. **3** shows prior art combustor **14**, which includes hot fuel nozzles **40H** and cold fuel nozzles **40C**. Hot fuel nozzles **40H** and cold fuel nozzles **40C** are disposed in a circumferential array at uniformly spaced intervals, S , around bulkhead **36**. Additionally, hot fuel nozzles **40H** and cold fuel nozzles **40C** are disposed such that hot fuel nozzles **40H** and cold fuel nozzles **40C** are arranged in an alternating pattern of H, C, H, C, etc. Uniform spacing of fuel nozzles can have destructive effects on the engine. For example, if there were four nozzles uniformly spaced 90 degrees apart then as the engine rotates it would see four disturbances. As the engine is rotating at a constant speed then the disturbances occur as beats uniformly spaced in time causing a constant frequency. If this frequency is close to a resonance frequency of the rotating elements of the engine then those elements can be excited by this frequency. This excitation can be destructive to the rotating elements. This theory is well understood in turbo-machinery and is typically employed in selecting the number of stationary elements, such as stators and vanes. The number of stationary elements is typically chosen to be a prime number in order to reduce the number of excitation frequencies. However, it is possible to space nozzles non-uniformly with a non-prime numbered array of nozzles. This non-uniform spacing results in smaller disturbance frequencies that is experienced by the engine components.

In contrast to the prior art, the present invention is an arrangement of fuel nozzles in a non-alternating pattern in order to avoid possible aerodynamic excitations downstream and to average out the cool and hot streaks for providing more uniform downstream temperatures. The non-alternating pattern of nozzles allows for more non-uniform spacing between nozzles to be employed. This non-uniform spacing follows a general rule that the space between any two cold nozzles (S_{CC}) is less than the space between a cold and hot nozzle (S_{CH}) which in turn would be less than the space between any two hot nozzles (S_{HH}). Placing two nozzles of the same type, hot or cold, adjacent to each other, rather than alternating hot and cold nozzles allows for non-uniform spacing while still maintaining uniform temperatures. Non-uniform spacing of the nozzles creates non-uniform spacing of aerodynamic disturbances and can result in uniform thermal profiles given nozzles with different levels of temperature increases are employed. Therefore, no strong disturbance frequencies are generated on the rotating

elements and the uniform thermal profiles provide for better life of the stationary turbine nozzle. Additionally, the more uniform turbine inlet temperature results in increased life of turbine sections parts.

FIG. 4 shows combustor **14A** according to a first embodiment, which includes a plurality of hot fuel nozzles **40H** and cold fuel nozzles **40C** disposed in a circumferential array around bulkhead **36**. First quadrant **Q1** has hot fuel nozzles **40H** alternating with cold fuel nozzles **40C**. Second quadrant **Q2** has two hot fuel nozzles **40H** adjacent to each other. According to the present embodiment, first quadrant **Q1** contains equally spaced fuel nozzles of spacing S_{CH} while second quadrant contains hot fuel nozzles which are spaced by S_{HH} . In an embodiment spacing S_{HH} is different from spacing S_{CH} .

FIG. 5 shows combustor **14B** according to a second embodiment, which includes a plurality of hot fuel nozzles **40H** and cold fuel nozzles **40C** disposed in a circumferential array around bulkhead **36**. The array of fuel nozzles **40H** & **40C** is arranged such that there is at least one hot fuel nozzle **40H** located immediately adjacent to another hot fuel nozzle **40H** (in this example, the hot fuel nozzles **40H** are located in both the first quadrant **Q1** and third quadrant **Q3** and located immediately adjacent to another hot fuel nozzle **40H**). There is also at least one cold fuel nozzle **40C** located immediately adjacent to another cold fuel nozzle **40C** (in this example, the two adjacent cold fuel nozzles **40C** are located in both the second quadrant **Q2** and fourth quadrant **Q4** and located immediately adjacent to another cold fuel nozzle **40C**). According to the second embodiment of the present invention, a non-alternating pattern of hot and cold fuel nozzles **40H** and **40C** are arranged on bulkhead **36** with non-uniform spacing that allows for a more uniform temperature distribution than from a fuel nozzle arrangement which contains an alternating fuel nozzle pattern.

FIG. 6 shows combustor **14C** according to a third embodiment, which includes a plurality of hot fuel nozzles **40H** and cold fuel nozzles **40C** disposed in a circumferential array around bulkhead **36**. The array of fuel nozzles is arranged such that there is at least one cold fuel nozzle **40C** located immediately adjacent to another cold fuel nozzle **40C** (in this example, the two adjacent cold fuel nozzles **40C** are located in first quadrant **Q1**). According to the third embodiment of the present invention, a non-alternating pattern of hot and cold fuel nozzles **40H** and **40C** are arranged on bulkhead **36** allowing for a non-uniform spacing that

results in a more uniform temperature distribution than from a fuel nozzle arrangement which contains an alternating fuel nozzle pattern.

FIG. 7 shows combustor **14D** according to a fourth embodiment, which includes a plurality of hot fuel nozzles **40H** and cold fuel nozzles **40C** disposed in a circumferential array around bulkhead **36**. The array of fuel nozzles is arranged such that hot and cold fuel nozzles **40H** and **40C** are non-uniformly spaced. For example, first quadrant **Q1** contains two cold fuel nozzles **40C** adjacent to each other. Extending radial lines to the two cold fuel nozzles **40C** located in the first quadrant **Q1** creates a segment S_{CC} in the first quadrant **Q1** which is 20° of the 360° annular combustor **14D**. Extending radial lines to the first cold nozzle **40C** located in the first quadrant **Q1** to the first hot nozzle **40H** located in the first quadrant **Q1** creates a segment S_{CH} which is 30° of the 360° annular combustor **14D**. Extending radial lines to the two hot fuel nozzles **40H** located in first quadrant **Q1** creates a segment S_{HH} which is 40° of the 360° annular combustor **14D**. Second quadrant **Q2**, third quadrant **Q3**, and fourth quadrant **Q4** contain hot fuel nozzles **40H** that are separated from an adjacent fuel nozzle by 40° . The difference in degrees of separation between fuel nozzles located in first quadrant **Q1** and the other quadrants, and the circumferential placement of hot and cold fuel nozzles **40H** and **40C** around the annular bulkhead, creates a non-uniformly spaced pattern of hot and cold fuel nozzles **40H** and **40C**. According to the fourth embodiment of the present invention, a non-uniformly spaced pattern of hot and cold fuel nozzles **40H** and **40C** is arranged on bulkhead **36** allowing for a more uniform temperature distribution than from a fuel nozzle arrangement which contains a uniformly spaced fuel nozzle pattern.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS:

1. A fuel nozzle arrangement comprising:
an annular combustor having four quadrants;
a plurality of fuel injectors disposed in the four quadrants;
5 a plurality of fuel nozzles of a first type and second type disposed onto the injectors so that each injector has either one first type fuel nozzle or one second type fuel nozzle attached to it; and
an array of the first type fuel nozzles and second type fuel nozzles in which at least two nozzles of the same type are adjacent to each other, rather
10 than alternating the first type fuel nozzles and second type fuel nozzles.
2. The arrangement of claim 1, wherein the fuel nozzles are disposed in a circumferential array.
3. The arrangement of claim 2, wherein the fuel nozzles of the circumferential array are spaced non-uniformly.
- 15 4. The arrangement of claim 1, wherein at least one type of fuel nozzle is located adjacent to an identical type of fuel nozzle.
5. The arrangement of claim 1, wherein the first type fuel nozzles produce more BTU's (British Thermal Units) than the second type fuel nozzles.
6. The arrangement of claim 1, wherein the four quadrants divide the annular
20 combustor into four 90° segments.
7. A gas turbine engine comprising:
a compressor section;
the combustor receiving air from the compressor section; wherein the
combustor comprises the circumferential array fuel nozzles in a non-
25 symmetrical pattern; and
a turbine section receiving combustion gases from the combustor and driving the compressor section,.
8. The gas turbine engine of claim 7, wherein the non-symmetrical pattern of the fuel nozzle arrangement is effective to provide a more uniform temperature distribution than
30 from a symmetric fuel nozzle arrangement.

9. The gas turbine engine of claim 7, wherein the combustor is an annular combustor having four quadrants; and wherein the circumferential array includes first type fuel nozzles and second type fuel nozzles.

10. The gas turbine engine of claim 9, wherein at least two of one type of fuel nozzle is located adjacent to an identical type of fuel nozzle.

11. The gas turbine engine of claim 9, wherein the first type fuel nozzles produce more BTU's (British Thermal Units) than the second type fuel nozzles.

12. The gas turbine engine of claim 7, wherein the fuel nozzles of the circumferential array are spaced non-uniformly.

13. A fuel nozzle arrangement comprising:
an annular combustor;
a plurality of fuel injectors disposed in the combustor;
a plurality of first type fuel nozzles and second type fuel nozzles disposed onto the injectors so that each injector has either one first type fuel nozzle or one second type fuel nozzle attached to it; and
an array of the first and second type fuel nozzles wherein the fuel nozzles are arranged in a non-alternating pattern of first type fuel nozzles and second type fuel nozzles.

14. The arrangement of claim 13, wherein:
the annular combustor has four quadrants; and
at least two quadrants contain an unequal number of first type fuel nozzles and second type fuel nozzles.

15. The arrangement of claim 14, wherein at least one two of one type of fuel nozzle is located adjacent to an identical type of fuel nozzle.

16. The arrangement of claim 13, wherein the fuel nozzles of the circumferential array are spaced non-uniformly.

17. A fuel nozzle arrangement comprising:
an annular combustor;
a plurality of fuel injectors disposed in the combustor;

a plurality of fuel nozzles of a first type and second type disposed onto the injectors so that each injector has either one first type fuel nozzle or one second type fuel nozzle attached to it; and

an array of the first type fuel nozzles and second type fuel nozzles, wherein the fuel nozzles are arranged in a non-uniformly spaced circumferential array.

18. The arrangement of claim **17**, wherein the annular combustor has four quadrants; and wherein at least two quadrants contain an unequal number of first type fuel nozzles and second type fuel nozzles.

19. The arrangement of claim **18**, wherein at least one quadrant is bounded by a first type fuel nozzle and contains at least one first type fuel nozzle and one second type fuel nozzle.

20. The arrangement of claim **17**, wherein at least two nozzles of the same type are adjacent one another.

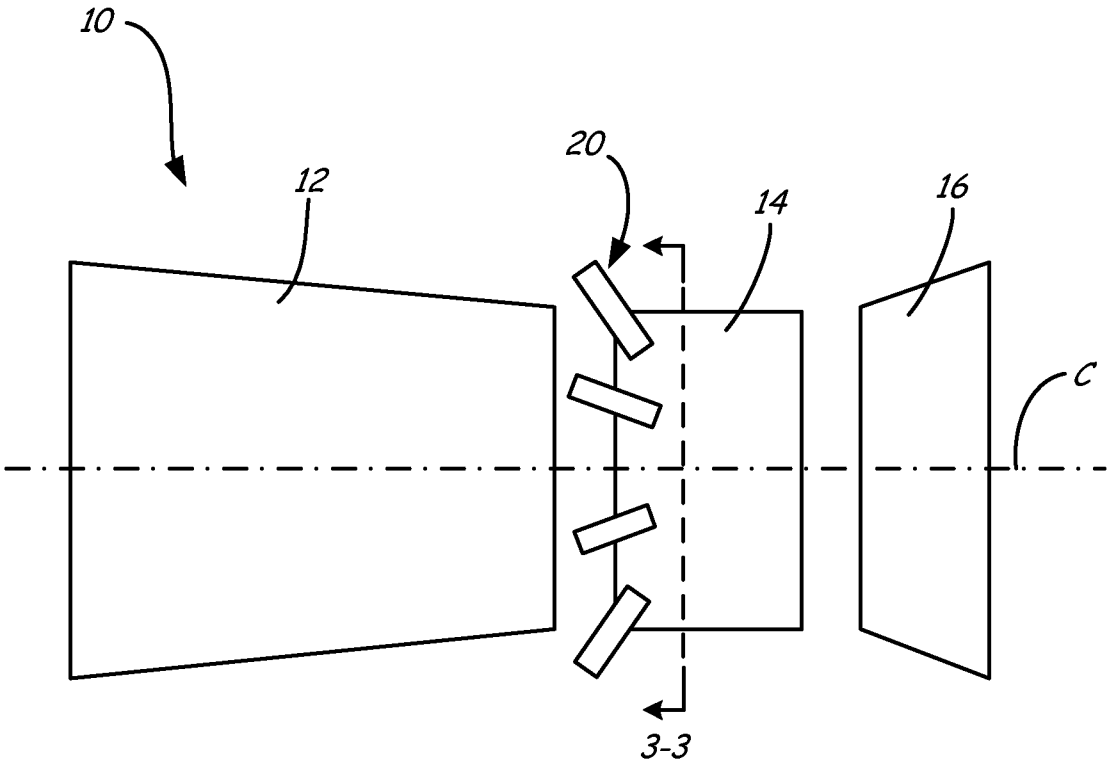
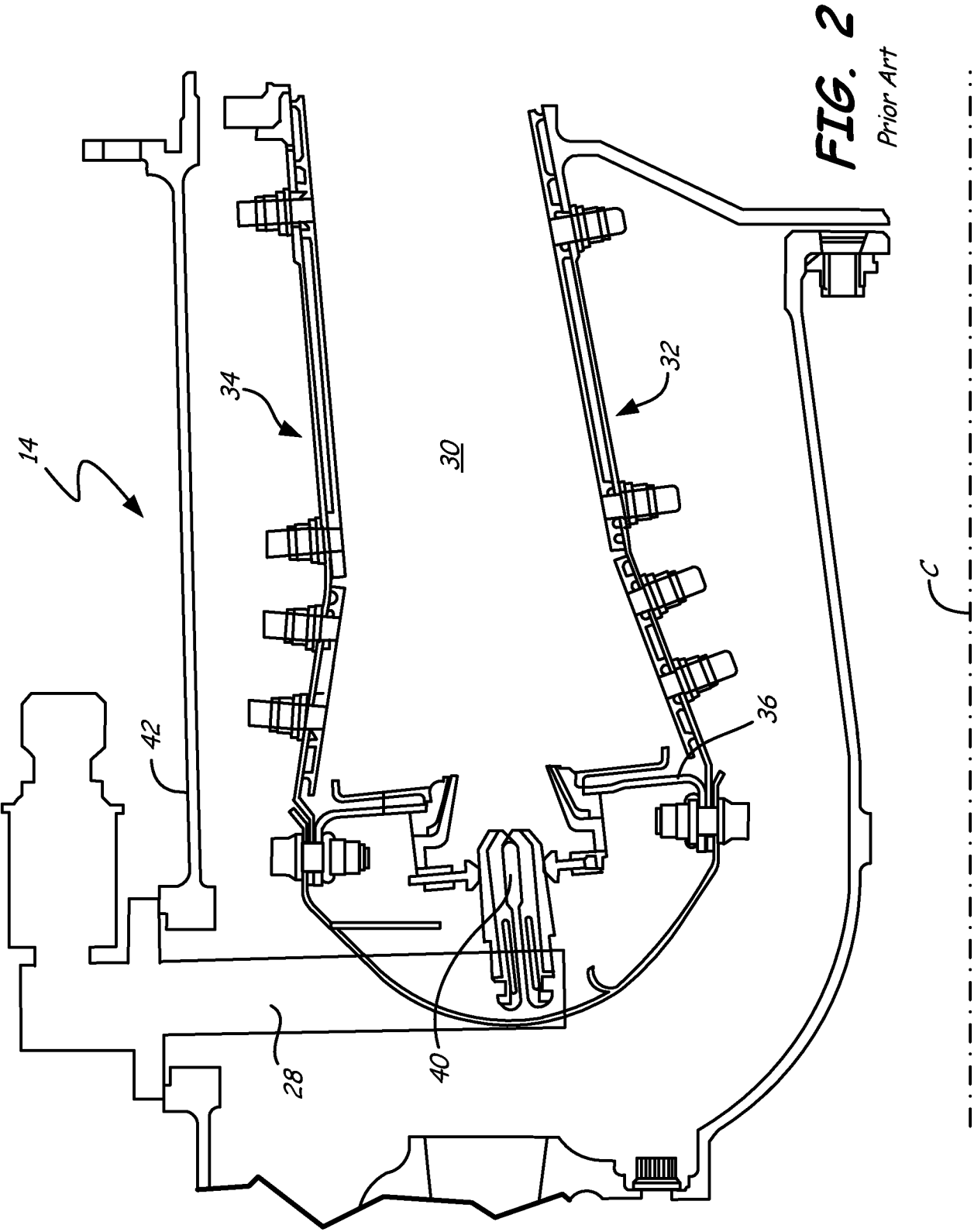


FIG. 1
Prior Art



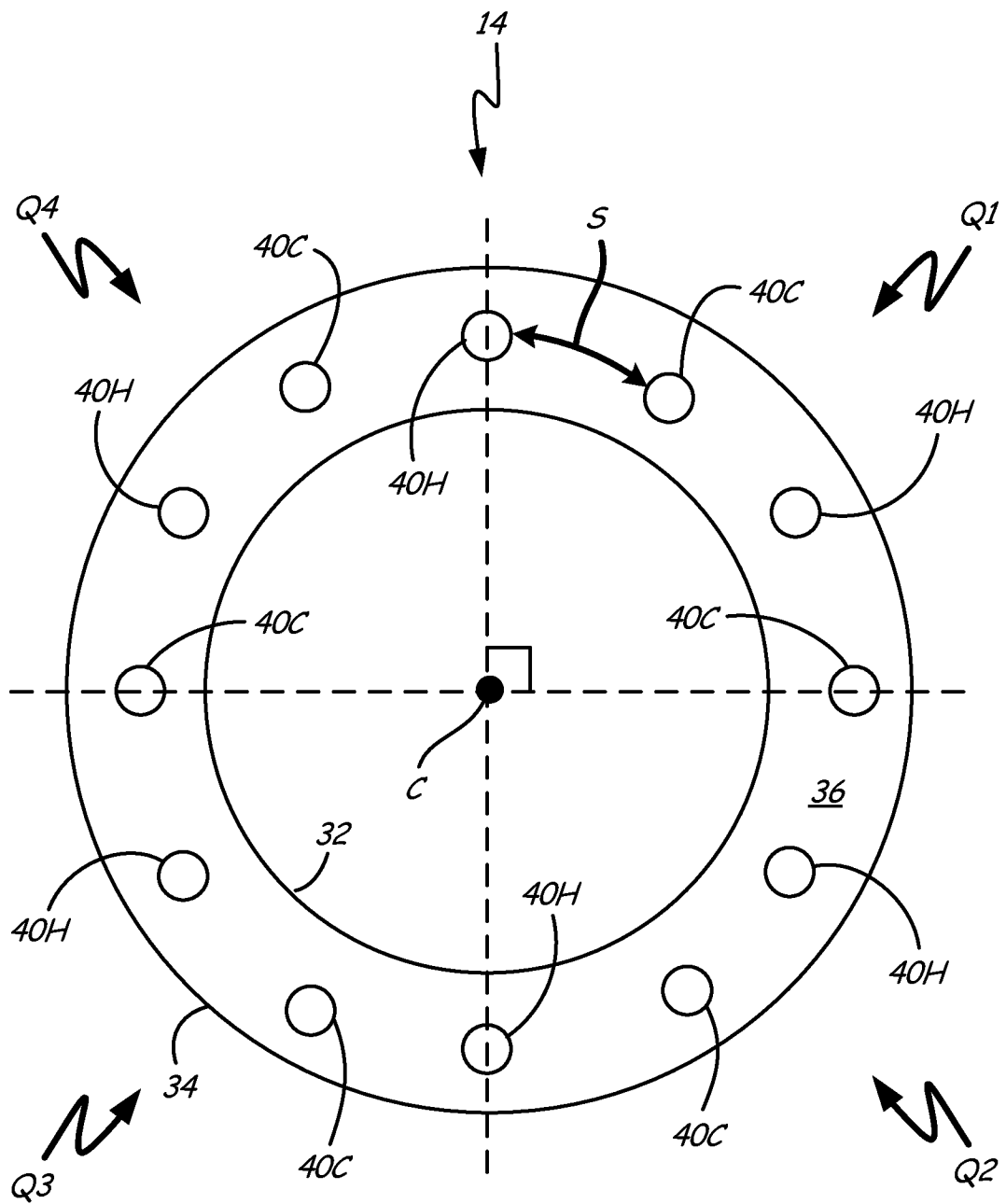


FIG. 3

Prior Art

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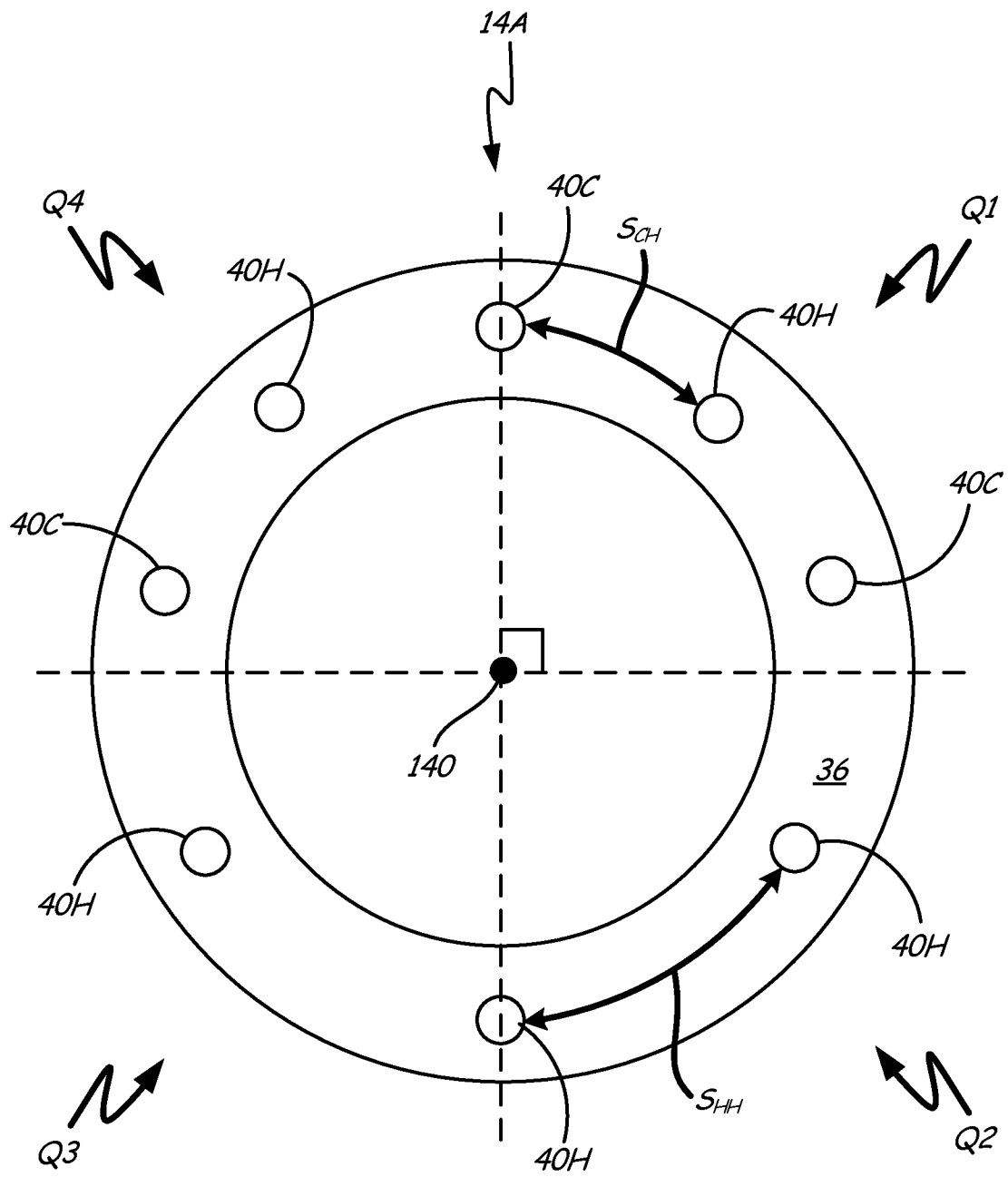
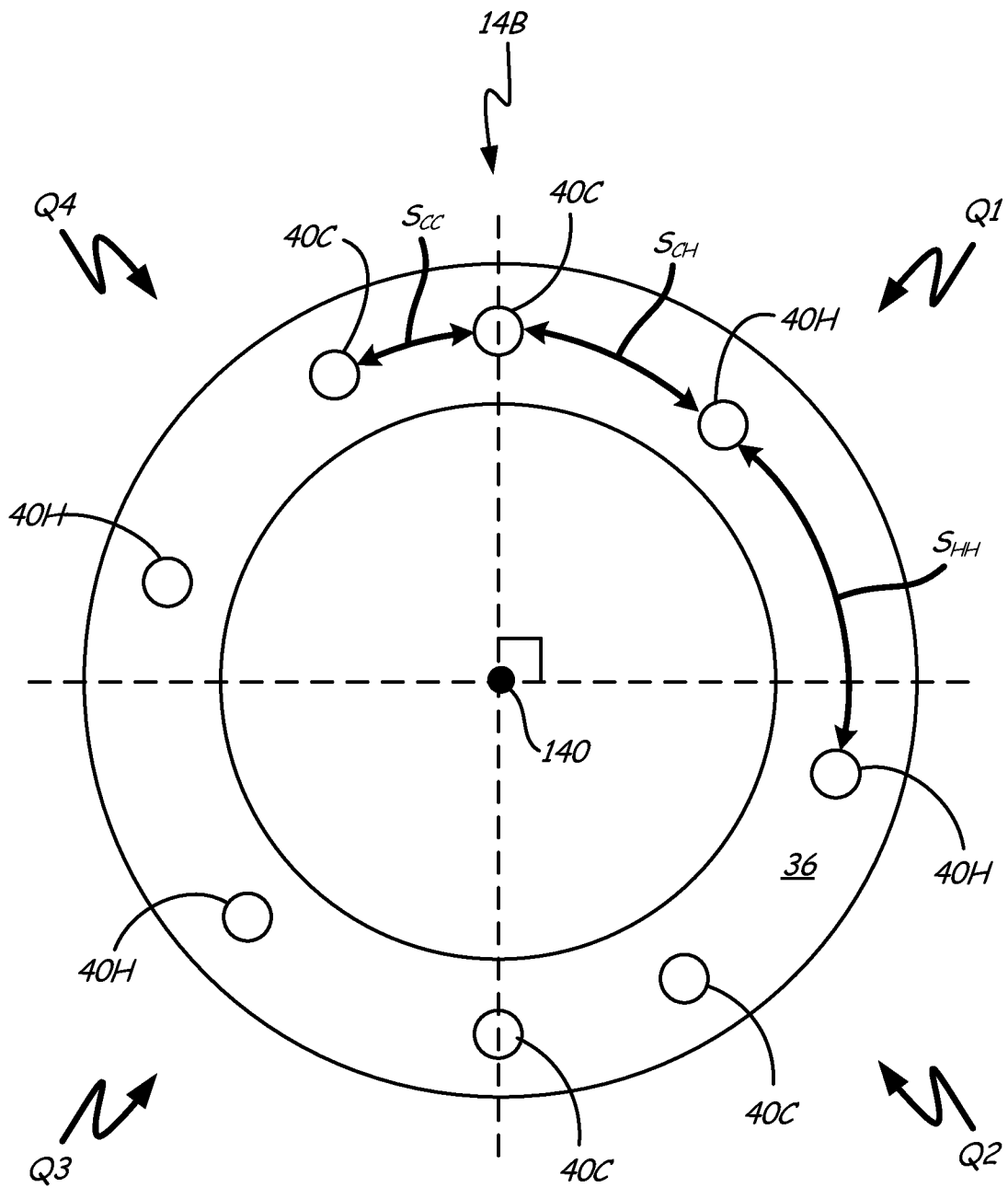


FIG. 4

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**FIG. 5**

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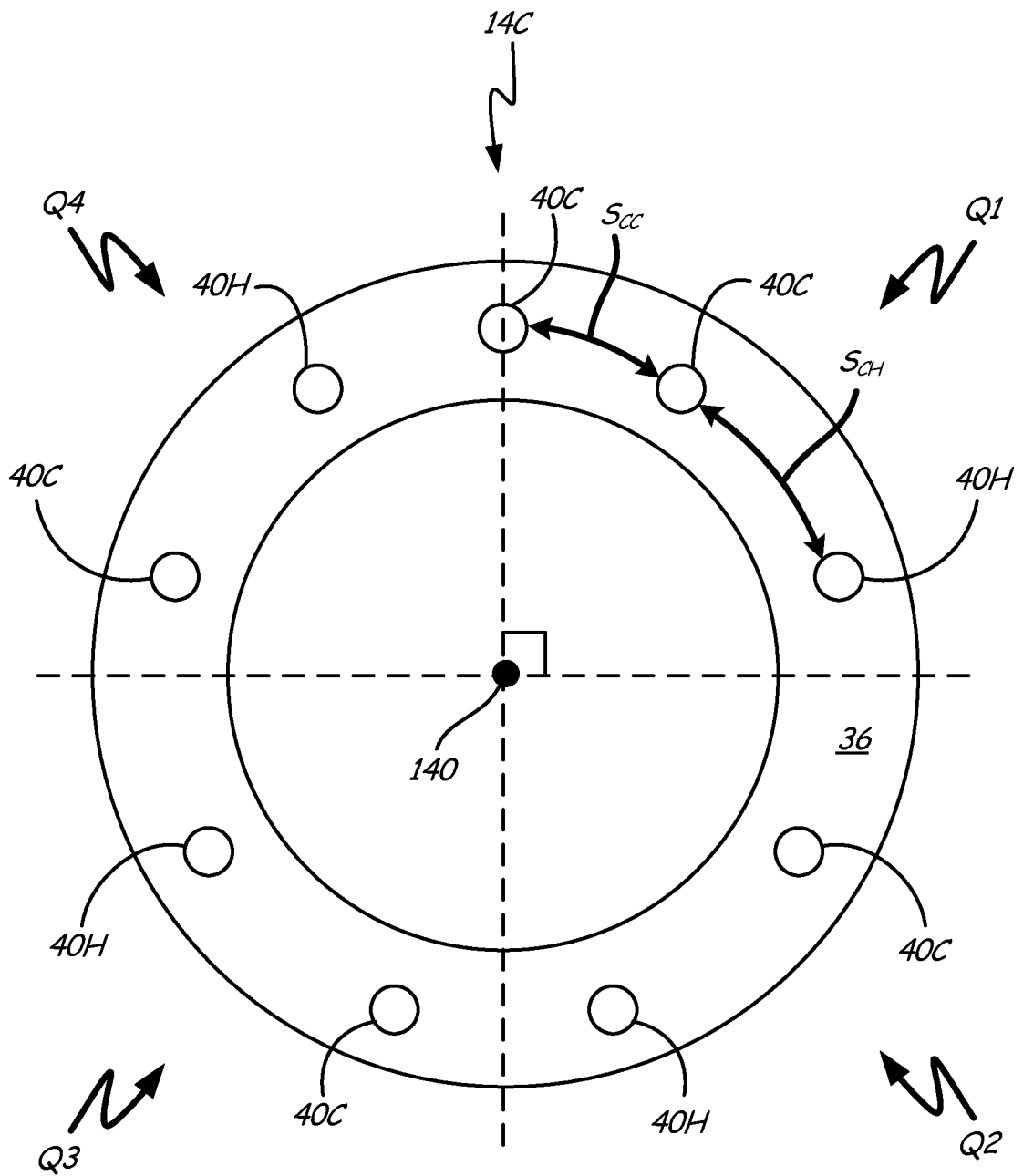
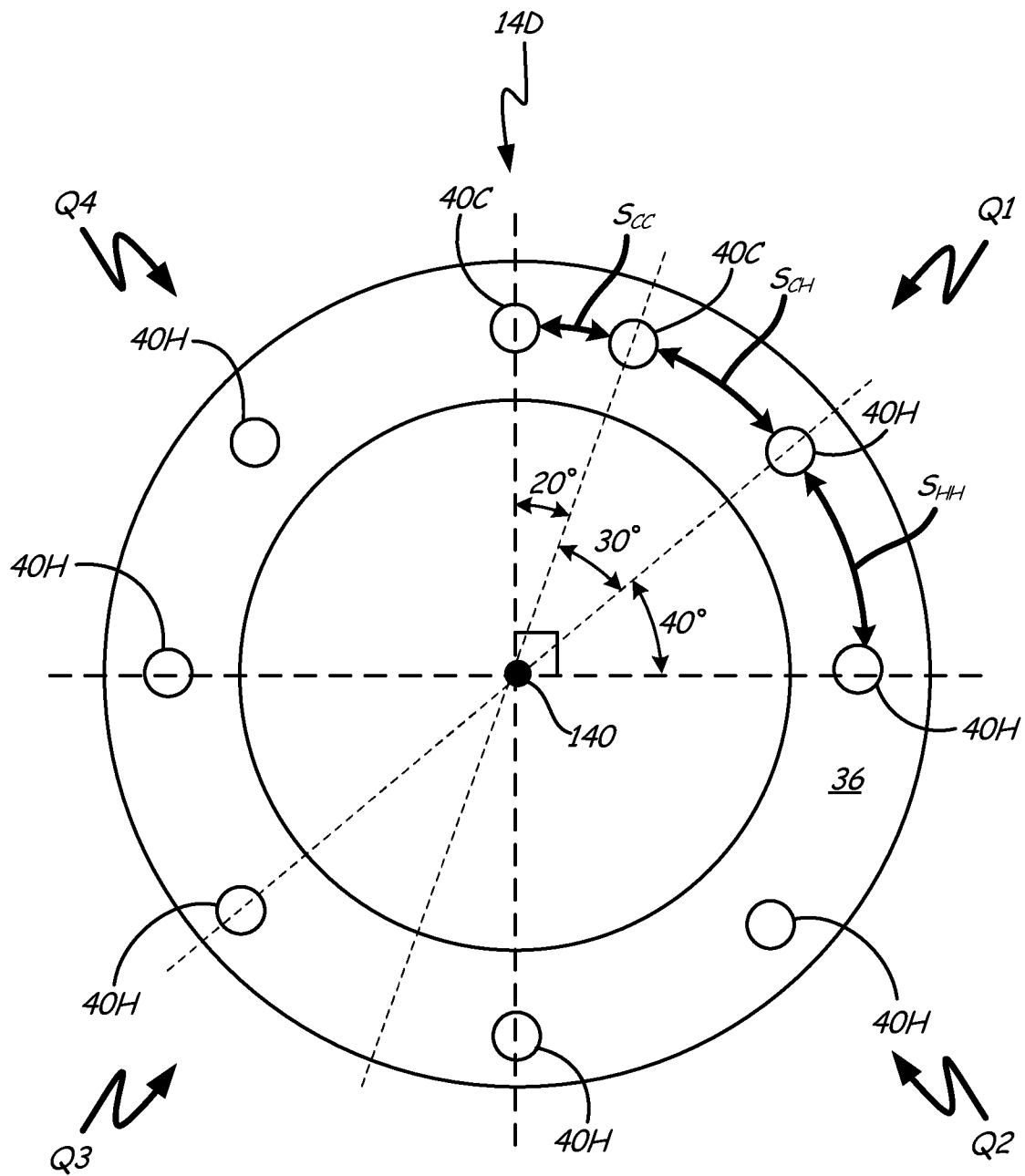


FIG. 6

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**FIG. 7**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/049241**A. CLASSIFICATION OF SUBJECT MATTER****F23R 3/20(2006.01)i, F02C 7/22(2006.01)i, F02C 3/14(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F23R 3/20; F02C 7/26; F02C 7/22; F02C 7/18; F02C 3/04; F02C 7/228; F02C 3/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: gas turbine engine, combustor, injector, and nozzle

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,817,389 A (HOLLADAY et al.) 04 April 1989 See column 2, line 44 - column 4, line 11; figures 1-3.	13-15
Y		1, 2, 4-6
A		3, 7-12, 16-20
Y	US 5,884,483 A (MUNRO, KEVIN M) 23 March 1999 See column 2, lines 16-37; figure 1.	1, 2, 4-6
A	US 2012-0060507 A1 (KING et al.) 15 March 2012 See paragraphs [0039],[0040]; figure 3.	1-20
A	US 6,945,053 B2 (VON DER BANK, RALF SEBASTIAN) 20 September 2005 See column 3, lines 18-67; figures 1-7.	1-20
A	US 8,024,934 B2 (ABREU et al.) 27 September 2011 See abstract; column 4, lines 3-32; figure 3.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 October 2013 (15.10.2013)

Date of mailing of the international search report

16 October 2013 (16.10.2013)

Name and mailing address of the ISA/KR

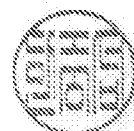
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/049241

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